Factors Affecting Fuel Consumption in Household Cooking in El-Salam Locality, South Kordofan State, Sudan

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ABSTRACT

The aim of this study was to determine the factors affecting fuel consumption in household cooking in El-Salam Locality as a contribution to solving problems of energy and forest resource management. The specific objectives were to a) study the socioeconomic factors related to type of fuel and fuel acquisition and use, b) study factors related to composition and level of consumption of household fuels and c) develop econometric models to estimate household fuel consumption. Data collected, using a structural questionnaire, were analyzed using descriptive statistics, ANOVA and regression analysis. Sample size was 382 respondents selected using multistage random sampling, where 23 villages (25% out of 93) were first randomly selected. Secondly, for each village the sample size was determined in proportion to total population, and respondents were selected randomly. The main results showed that the type of fuel used was related to the location of the administration units, type of house construction material and education level of head of household. Regression results showed that the level of firewood consumption was related positively to availability of alternative fuels and household size and negatively to education level of the head of household and price of firewood. Consumption level of charcoal was related positively to household size and price of alternative fuel and negatively to the price of charcoal and household income. Liquefied petroleum gas consumption was related positively to education level of the first wife, income and degree of urbanization and negatively to type of house construction material. It is concluded that socioeconomic factors should be taken in consideration if sound energy planning is to be pursued.

Key words: Cooking; energy; household; factors; South Kordofan State
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INTRODUCTION

It is expected that approximately 2.5 billion people in developing countries rely on biomass fuels to meet their cooking needs. For many of these countries, more than 90 percent of total household fuel is biomass. Without new polices, the number of people

that rely on biomass fuels is expected to increase to 2.6 billion by 2015, and 2.7 million by 2030 due to population growth (IEA 2006, cited in Mekonnen and Kohlin 2008). While rural households rely more on biomass fuels than those in urban areas, well over half of all urban households in Sub-Saharan Africa rely on fuelwood, charcoal, or wood waste to meet their cooking needs (IEA). With increasing population and urbanization over time, urban household energy is an important issue for developing countries in general.

Use of biomass fuels for cooking is a major cause of health problem in developing countries due to indoor air pollution (Bruce *et al.* 2000; Ezzati and Kammen 2001, cited in Mekonnen and Kohlin 2008). For example, the World Health organization (WHO) estimates that 1.5 million premature deaths per year are directly attributable to indoor air pollution from the use of solid fuels (IEA 2006). Recognizing the adverse effects of use of traditional biomass fuels, the United Nation Millennium Project recommends halving the number of household that depend on traditional biomass for cooking by 2015, which involve about 1.3 billion peoples switching to other fuels (IEA 2006).

In the literature on household energy demand and choice, it has been argued that households with low levels of income rely on biomass fuels, such as wood and dung, while those with higher incomes consume energy that is cleaner and more expensive, such as electricity (Hosier and Dowd 1987; Barnes and Floor 1999; Heltberg 2005, cited in Mekonnen and Kohlin 2008). More recently, it has been argued that household in developing countries do not switch to modern energy sources but instead tend to consume a combination of fuels, which may include combining solid fuels with non-sold fuels as sources of energy. Thus, instead of moving up the ladder step by step as income rises, households choose different fuels as from a menu. They may choose a combination of high-cost and low cost fuels, depending on their budgets, preferences, and needs (World Bank 2003, cited in Mekonnen and Kohlin 2008). This lead to the concept of fuel stacking (multiple fuel use) as opposed to fuel switching or an energy ladder (Masera *et al.* 2000; Heltberg 2005, cited in Mekonnen and Kohlin 2008).

In Sudan the household sector consumes about 60% of total energy consumption. This shows a negative economic indicator, where energy is mainly consumed in non-productive end uses. Household energy consumption is mainly in terms of biomass energy, and mainly used for cooking purposes. Charcoal is the main cooking fuel for urban households, while firewood is the main cooking fuel for rural households. The national per capita consumption of firewood is 0.273 ton/year, while the consumption of charcoal per capita is 0.0667 ton. Agricultural residues constitute a considerable share representing more than 12%, of total household energy (Ministry of Electricity, 2004).

Sudan depends heavily on its forests and biomass resources for the satisfaction of energy requirements. In this respect, 80.5% of the Sudan energy consumption is derived from wood and biomass (66.9% wood fuel and 13.6% agricultural and animal residues), in comparison to 17.1% petroleum products and 2.4% hydro-electric power. In 1999

Sudan's energy consumption amounted to about 10 million tons of oil equivalent (TOE), (Ministry of Energy and Mining, 2001).

Fuel wood as a renewable energy in Sudan is not supplied in a sustainable manner. This has lead to serious environmental problems because of large-scale deforestation. At the same time there are many other energy substitutes, such as kerosene and LPG, which are environmentally favored but have no significant contribution in country's energy supply especially in rural areas. In Sudan the main cause of forest degradation is tree cutting for wood fuel which constitutes more than 70% of the total national energy. The annual rate of Sudan population growth is 2.6%, the demand for biomass energy can be assumed to grow at about the present national consumption rate of 0.71 cubic meter per capita, the present annual total consumption of wood was estimated at 15.8 million cubic meters. This is equivalent to harvesting three million feddans (one feddan = 0.42 ha) of natural forest (one feddan produces 5.22 cubic meters of solid dry wood) (Hasab elrasoul, 1999).

The aim of this study was to determine the factors affecting fuel consumption in household cooking in El-Salam Locality (South Kordofan State). The specific objectives were to: a) study the socioeconomic factors related to type of fuel, fuel acquisition and use, b) study factors related to composition and level of consumption of household fuels and c) develop econometric models to estimate household fuel consumption.

MATERIALS AND METHODS

Data collection:

Data was collected using a structural questionnaire. Sample size was 382 respondents selected using multistage random sampling (Elrofaei, 1999), where 23 villages (25% out of 93) were first randomly selected. Secondly, for each village the sample size was determined in proportion to total population, and respondents were selected randomly from a list provided by local authorities.

Two types of interviews took place, the first one regarding the general information about the village such as size, social services, economic activities and production (both crops and animals). This was made through a group discussion with the leaders of the villages (sheikhs) in the presence of other villagers, mostly the leaders and the elders in each village. The second type was carried out at the household level by face-to-face interviews of the head of household or one of his/her relatives if he/she is absent, to collect information about household characteristics and fuels used by households.

Data analysis:

The analytical techniques employed in the study include descriptive statistics to present type of fuel, availability, acquisition and use, the economic and social data including mean, standard deviation, percentages, distribution and cross tabulation.

Comparison of fuel quantities was done using ANOVA tests. Regression analysis was used to estimate consumption functions for fuels mostly used by the households.

The theoretical model: Household fuel consumption:

The standard model of fuel consumption can be written as follows (Kevin *et al*. 1990).

$$Q_{ij} = f\ (Y_i, N_i, P_{ij}, P_{ik}, A_{ij}, A_{ik})$$

Where:

Q_{ij} = the energy content of fuel j used by household i (this equation is estimated separately for each fuel and each major end-use, such as cooking in our case).

Y_i = household income for household i.

N_i = family size of household i.

P_{ij} = the price of fuel j facing household i.

P_{ik} = the price of competing fuel k (k=1, 2……n) facing household i.

A_{ij} = appliance prices facing household i for fuel j.

A_{ik} = appliance prices facing household i for appliance for fuel (k= 1, 2…..n).

For the purpose of our study, a modified model was used, where appliance price factors (A_{ij}, A_{ik}) were removed from the model as they do not vary much in a given area. Instead, a variable indicating fuel availability and a vector representing social characteristics was used.

The modified model used in this study was (Kevin. *et al* 1990).

$$Q_{ij} = f\ (Y_i, N_i, P_{ij}, P_{ik}, H_i, A, B)$$

Where:

Q_{ij}= the energy content of fuel j used by household i,

Y_i= household income for household i.

N_i= family size for household i.

P_{ij}= the price of fuel j facing household i.

P_{ik}= the price of competing fuel k (k=1, 2……n) facing household i.

K (k= 1, 2…..n)

H_i= cooking practices for household i.

A= availability of fuel I (measured in distance from household)

B= vector of social characteristics of household i.

RESULTS

Socioeconomic characteristics related to energy consumption:

The distribution of the respondents between urban and rural areas appeared to be almost equal (urban 51.3% while rural 48.7%). However, cross tabulation with administration units reveals that all respondents in Babanosa are urban while all respondents in Kejaira and El- Teboon are rural. On the other hand most respondents from El- Fula are urban (79.4%). Regarding the level of education of heads of households, about 30% have attended basic level schools, 22% have high school education and 13% Quranic School (*khalwa)*. About 10% have attended universities and only 1% has studied for higher degrees. Illiteracy represents about 26% of the population. This may indicates inadequacy of schools in the study area or inadequate concern towards education. However our concern here is whether this affects fuel consumption patterns.

Cross tabulating administration units and education level of heads of households within the locality reveals that illiteracy is highest in Kejaira (45.2%) followed by El-Fula (21.6%), El-Teboon (20%), and is least in Babanosa (12.2%) (Fig. 1). Moreover, the level of education of head of household is significantly related to mean annual household income where university graduates fall in the highest income group (c), basic and high school graduates fall in the second income group (statically fall in the same income group b) while illiterates and khalwa education level together with postgraduates form the third income group (a) at the bottom of the income scale (Fig. 2). The later because there is no available Jobs to the postgraduates in the area

The relationship between the type of fuel used in cooking and type of house building material is shown through χ^2 tests. Results showed that 95% of households using firewood have their all rooms in the house constructed of straw only. Over 80% of households using charcoal only have no rooms constructed of straw. All respondents using only LPG in cooking have no rooms constructed of straw. The introduction of a second type of energy changes the picture as follows. The addition of charcoal to firewood, as a mix of household cooking energy, results in more households having rooms constructed of non-straw material.

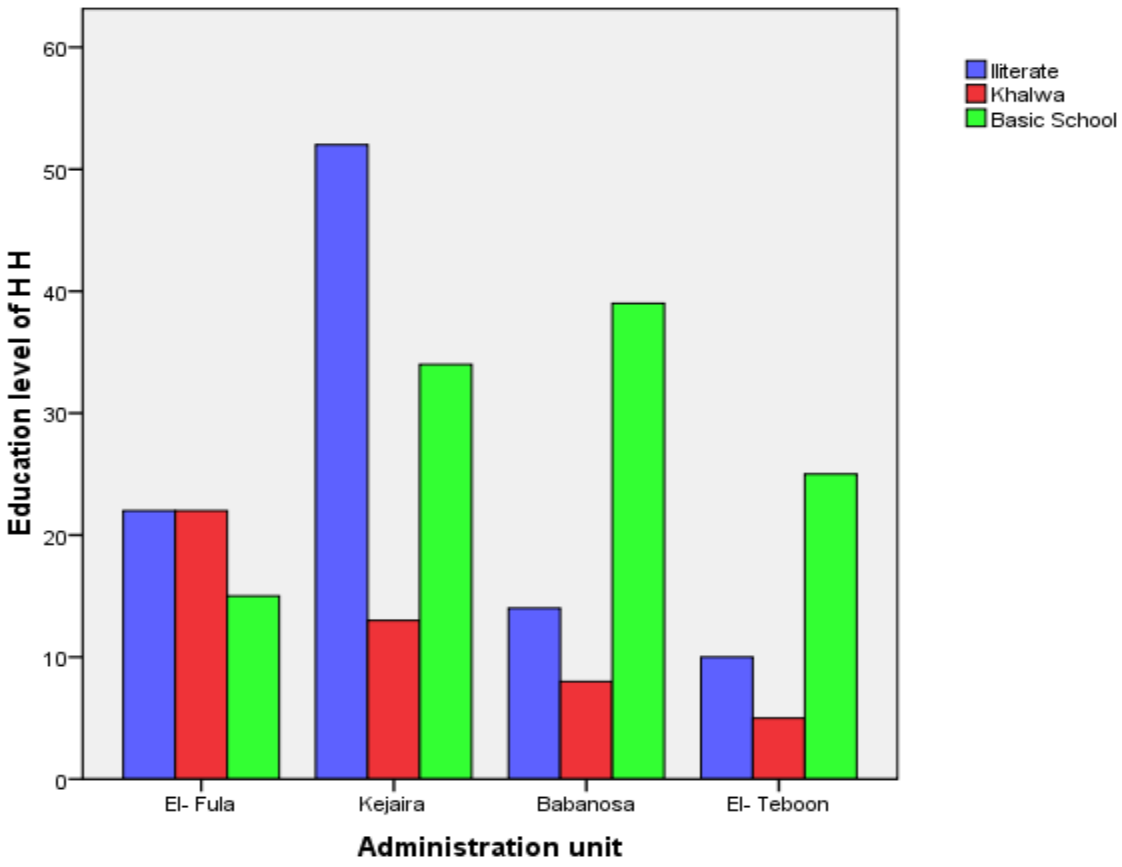


Figure 1. Education level of H Hs with different education levels grouped by administrative units in El Salam Locality

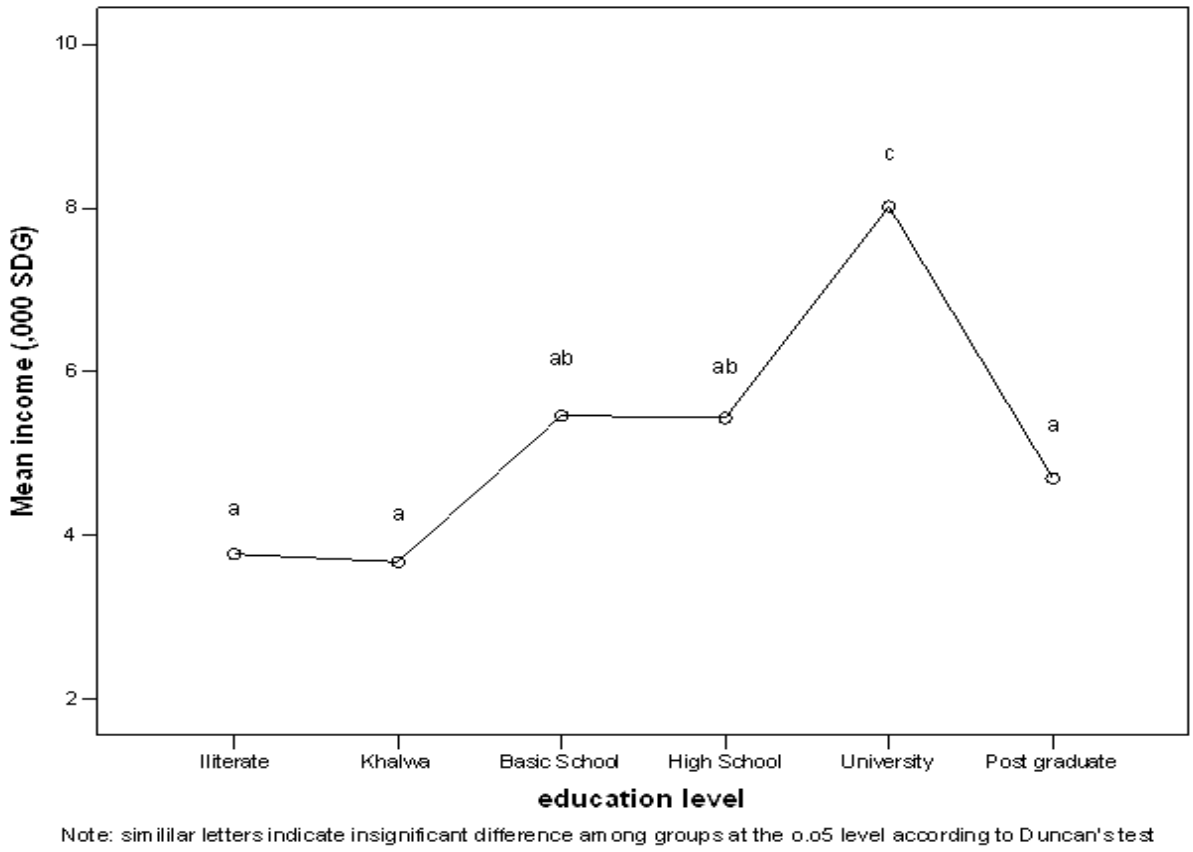


Figure 2. Mean of household annual income at different education levels in El Salam locality

Fuel type used seems to be related to the type of construction material of which household rooms are made. That is to say while using firewood is related to rooms constructed of non-straw material, using charcoal and LPG are associated with rooms made of material other than using only straw (Table 1).

Type of fuel used by the household is also related to education level of heads of households. Almost half of households using only firewood are illiterate. On the other hand, all of those using only LPG are university graduates, while half of households using only charcoal have basic school education. High school graduates seemed to use more varied types of fuel (Table 2).

Consumption of fuel in household cooking:

Mean annual household consumption of firewood in cooking was 2.03 (±1.9) TOE, while that of charcoal and LPG was 0.33 (± 0.28) TOE, and 27.65, respectively. Grouping consumption levels of firewood by administration units reveals that Babanosa was significantly of least consumption level (1.19 TOE), followed by El Fula and El-Teboon (average of 2 TOE), while Kejaira was of the highest average consumption level

of 2.9 TOE. As for charcoal the highest consumption was in Kejaira (average 0.46 TOE) followed by El Fula (0.44 TOE) and El Teboon and Babanosa at the last group (average of 0.34 TOE). LPG quantity was highest in Babanosa (67.75 TOE), followed by El Fula (22.44 TOE) and in the last group El Teboon and Kejaira (average of 3.3 TOE) (Figures 3.3 -3.5).

The education level of the head of households makes a difference in the quantity consumed of firewood and LPG, but not to that of charcoal. It was interesting to find out that the education level of the first wife makes a difference in quantity consumed for both firewood and LPG especially for the two illiterate and university levels, in the case of firewood and for the illiterate and high school levels in the case of LPG (Figures 3.6 through 3.9).

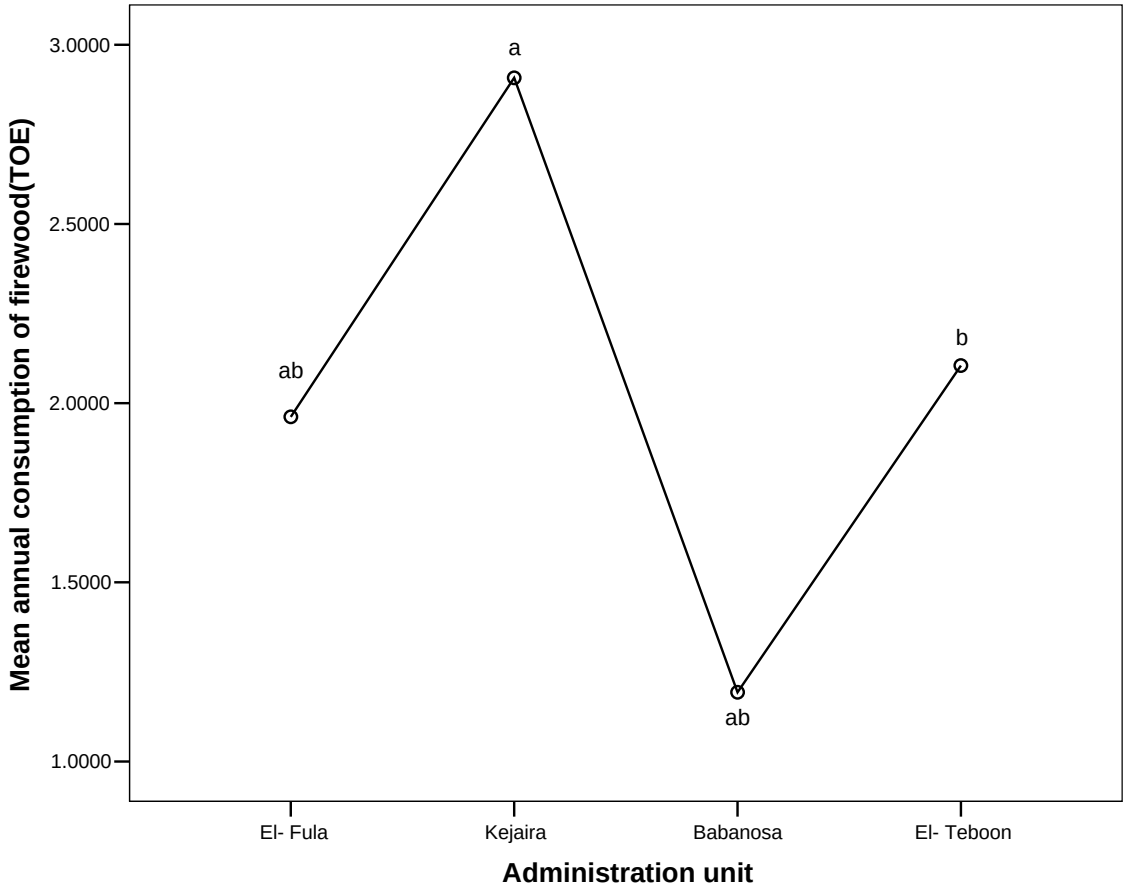
Table 1. Households room construction materials and types of cooking energy in El Salam Locality

Type of energy	House rooms made of		
	No straw	Straw only	Straw and other materials
Firewood	2.6%	94.9%	2.6%
Charcoal	80.0%		20.0%
LPG	100.0%		
Firewood and Charcoal	19.5%	65.6%	14.9%
Firewood, Charcoal, and LPG	59.6%	10.6%	29.8%
Charcoal and LPG	84.0%	12.0%	4.0%
Charcoal, Electricity and LPG	100.0%		
Firewood and LPG	66.7%	33.3%	
Firewood, Charcoal, LPG and Gasoil	100.0%		
Firewood, Charcoal, LPG and Kerosene			100.0%
Firewood, Charcoal, and Electricity	100.0%		
Firewood, charcoal LPG kerosene gasoil and plant residues	100.0%		
Firewood, Charcoal and Plant residues		100.%	
Total	33 %	52.5%	14.5%

Table 2. Frequency of households using different energy types for cooking, grouped by level of education, in El Salam Locality

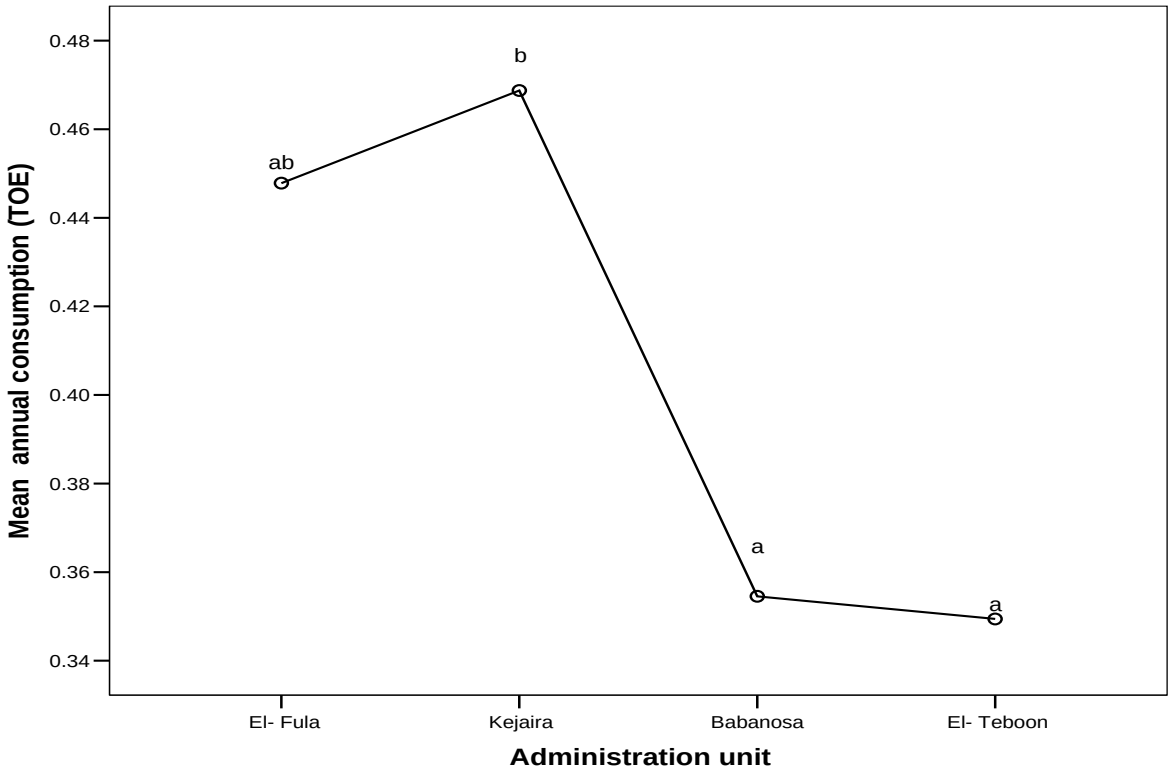
Type of energy	Education level of head of household					
	1	2	3	4	5	6
Firewood	47.7	15.4	27.7	7.7		1.5
Charcoal			50.0	16.7	33.3	
LPG					100	
Firewood and Charcoal	29.5	16.1	30.4	18.4	5.1	.5
Firewood, Charcoal, and LPG	1.8	5.5	30.9	30.9	27.3	
Charcoal and LPG			23.1	50.0	26.9	
Charcoal, Electricity and LPG			100.0			
Firewood and LPG	33.3			33.3	33.3	
Firewood, Charcoal, LPG and Gasoil				100		
Firewood, Charcoal, LPG and Kerosene				100		
Firewood, Charcoal, and Electricity				100		
Firewood, charcoal LPG kerosene gasoil and plant residues					100	
Firewood, Charcoal and Plant residues	100					
Total	25.7	12.6	29.6%	21.2	9.9	1.0

Note: 1= illiterate, 2= Khalwa, 3= basic school, 4= high school, 5=university, 6= postgraduate



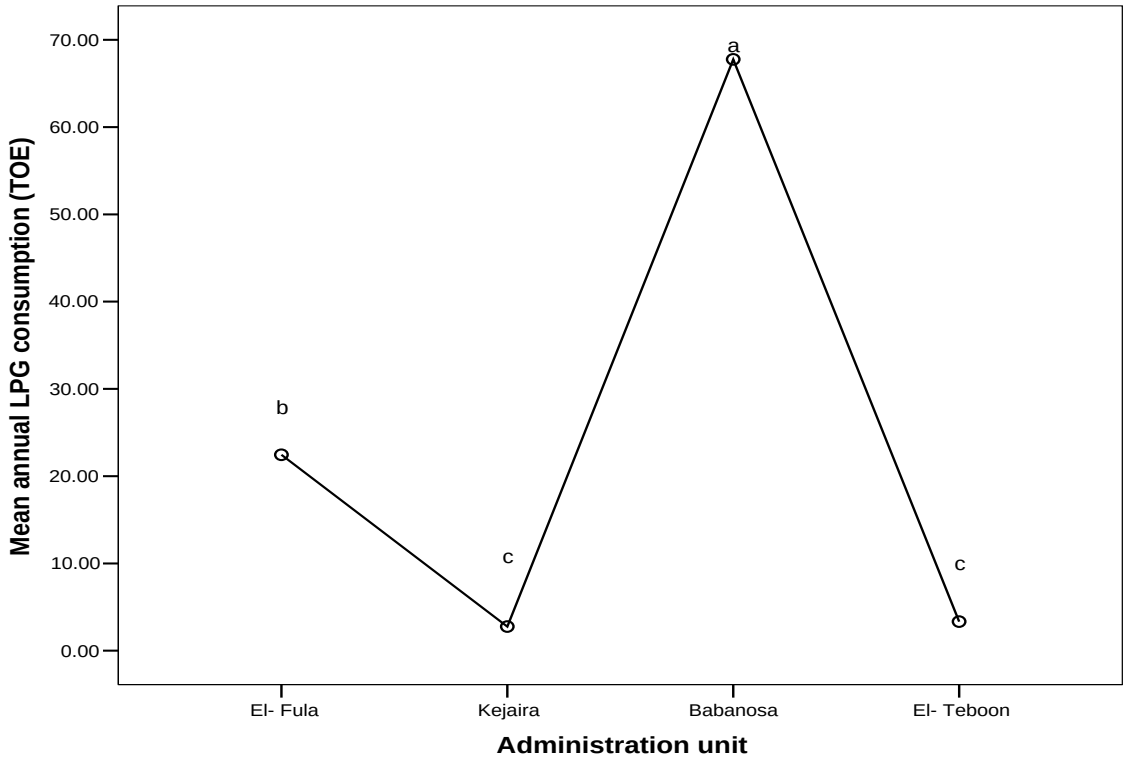
Note: different letters indicate statistically different means at the 0.05 level according to Duncan's test

Figure 3.3. Mean annual household consumption of firewood in cooking grouped by administration units in El Salam locality



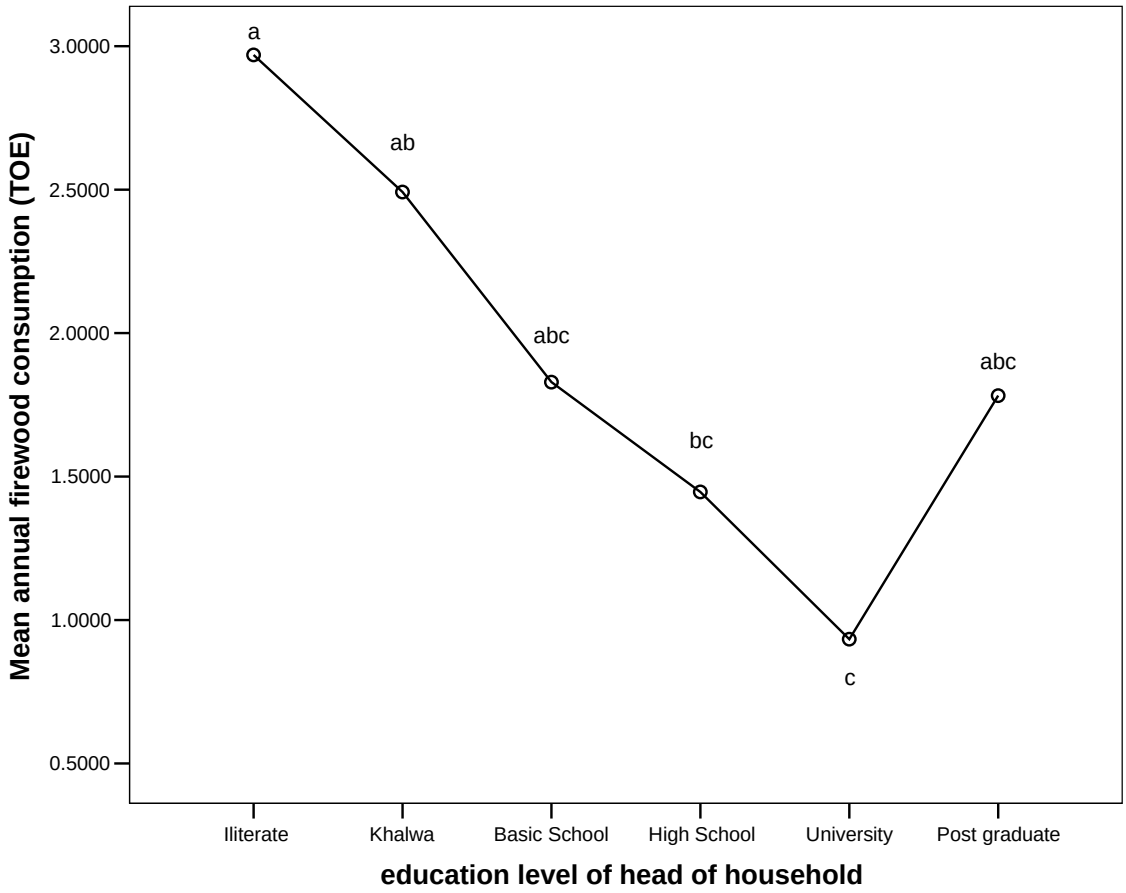
Note: different letters indicate statistically different means at the 0.05 level according to Duncan's test

Figure 3.4. Mean annual household consumption of charcoal in cooking grouped by administration units in El Salam locality



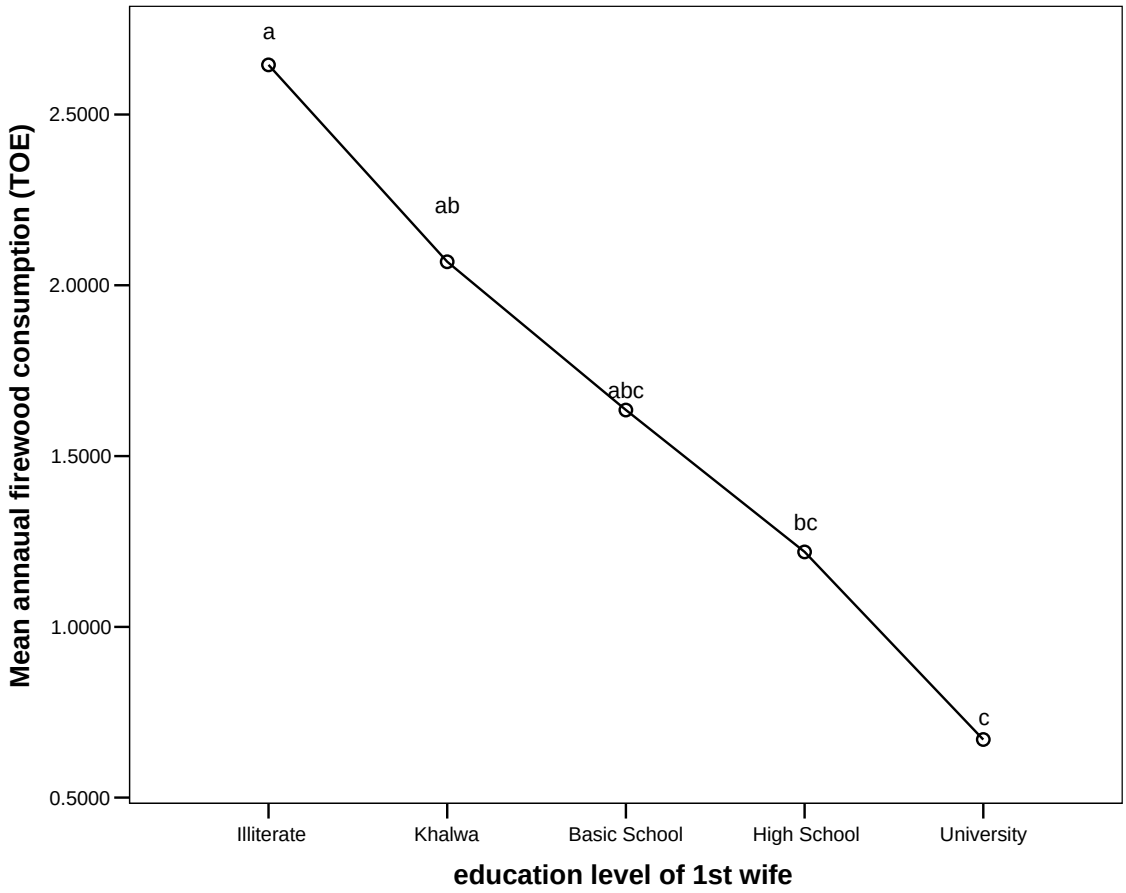
Note: different letters indicate statistically different means at the 0.05 level according to Duncan's test

Figure 3.5. Mean annual household consumption of LPG in cooking grouped by administration units in El Salam locality



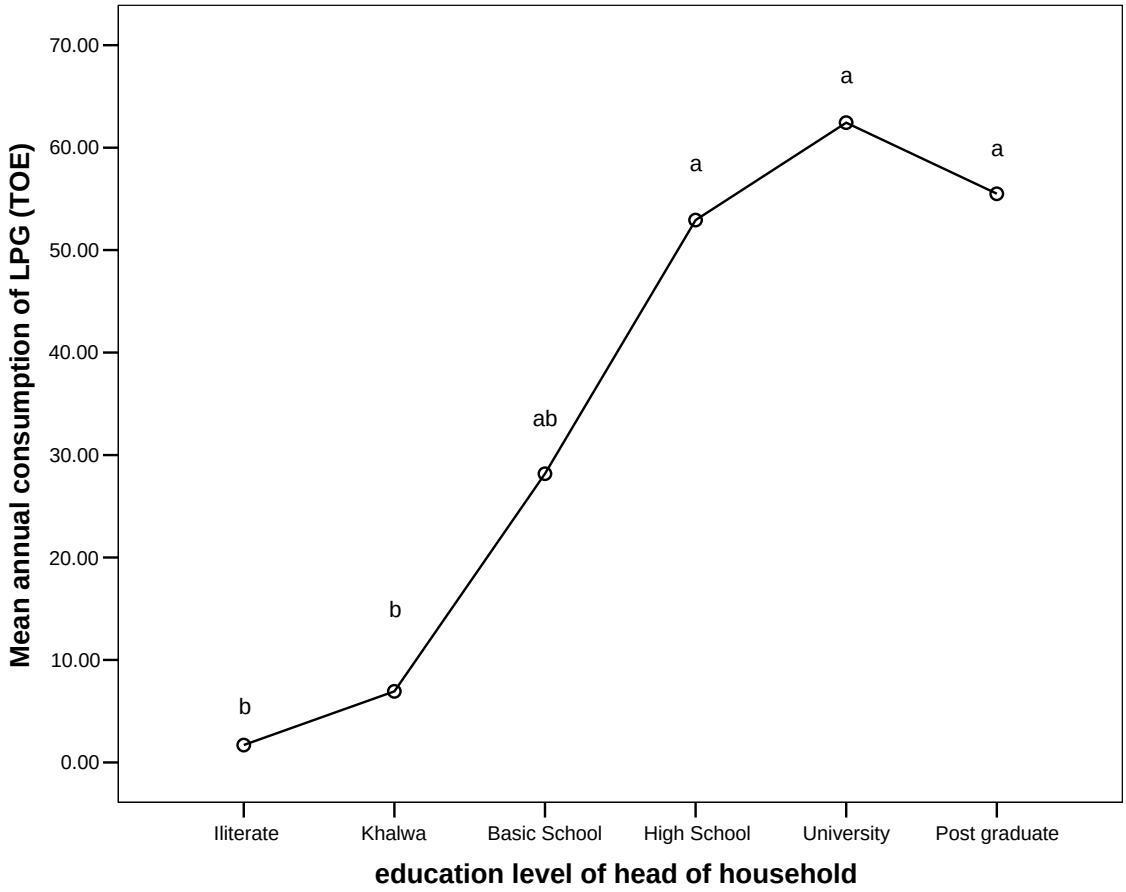
Note: similar letters indicate insignificant difference at the 0.05 level according to Duncan's test

Figure 3.6. Mean annual household consumption of firewood in cooking grouped by education level of head of household in El Salam locality



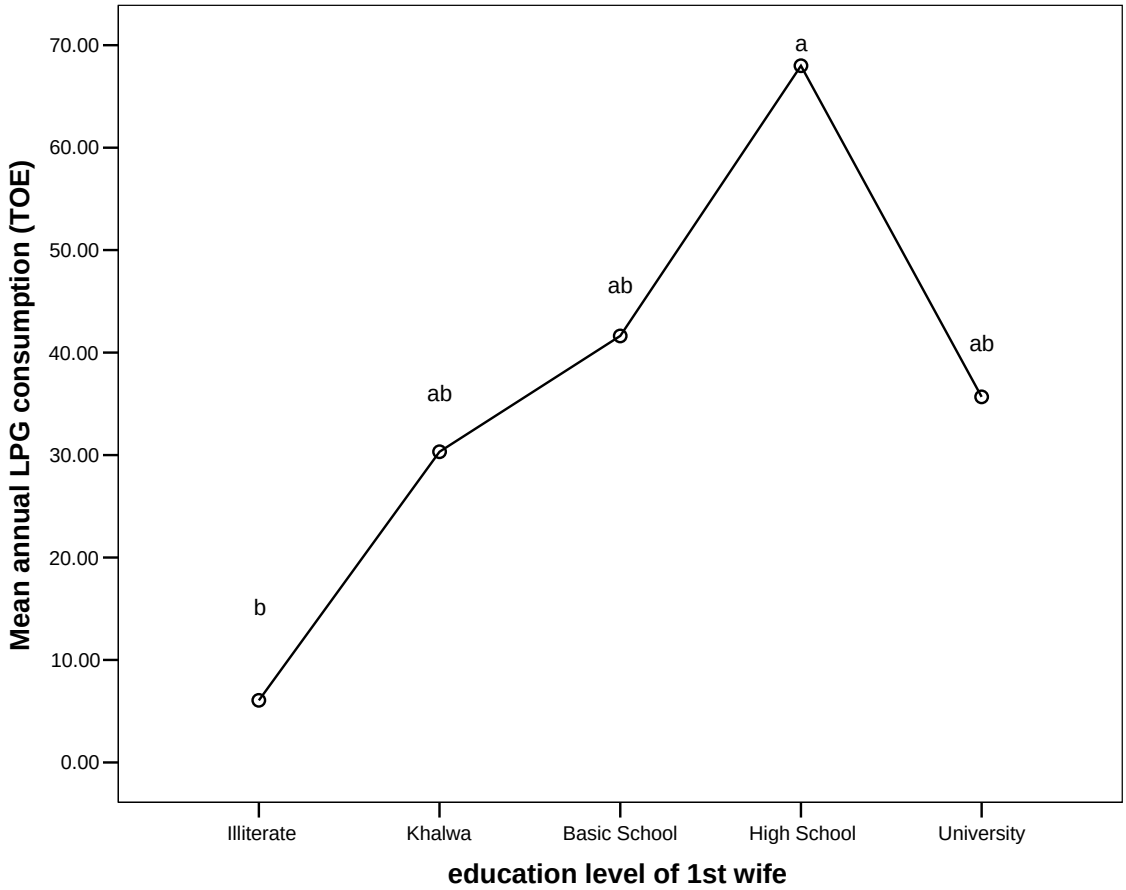
Note: similar letters indicate insignificant difference at the 0.05 level according to Duncan's test

Figure 3.7. Mean annual household consumption of firewood in cooking grouped by education level of first wife in El Salam locality



Note: similar letters indicate insignificant difference at the 0.05 level according to Duncan's test

Figure 3.8. Mean annual household consumption of LPG in cooking grouped by education level of head of household in El Salam locality



similar letters indicate insignifican difference at the 0.05 level according to Duncan's test

Figure 3.9. Mean annual household consumption of LPG in cooking grouped by education level of first wife in El Salam locality

Energy consumption models:

The following equations represent fuel consumption functions. Figures below coefficients, between parentheses, represent significance levels of the coefficients. R^2 is the coefficient of multiple correlations; F is the F-test.

i. Firewood consumption model

Equation 1 represents a consumption function for firewood

$$Q_{fr} = 2.47 + 0.109Fs - 26.6P_{fr} + 0.567\log A_{chr} - 0.582\log ED_h \quad (1)$$
$$(0.000)\ (0.000)\ \ (0.000)\ \ (0.037))\qquad (0.001)$$
$$R^2 = 0.25 \quad F = 19.788$$

The estimated model shows that the quantity of firewood consumed by households in El-Salam Locality is a function of household size (Fs), firewood price (P_{fr}), charcoal availability, measured in terms of the distance walked to acquisition the fuel (A_{fr}), and education level of head of household ($ED_{h)}$. An increase of household size by one more member increases firewood consumption by 0.109 TOE. A change in firewood price by one SDG will change firewood consumption by 26.6 TOE in the opposite direction. Improvement of charcoal availability (measured by decreasing distance of selling point) by 1% reduces firewood consumption by 0.567 TOE. As education level of the head of household improves by one level (e.g from illiterate to khalwa, or from basic to secondary), it reduces firewood consumption by 0.582 TOE.

All regressors are highly significant. Despite the low R^2, the present model is the best fitted given the data used. The low R^2 indicates that the factors included in the model are relevant and that other unknown factors are omitted. It might also be the case that there are numerous factors of minute individual effects that together can make a difference to R^2. It is also possible that other more forms could have been more suitable.

ii. Charcoal consumption model

Equation 2 represents the consumption function of charcoal

Q_{chr} =	1.109	-1.917 P_{Chr}	+ 0.065 P_{Lpg}	- 0.085 log Y	+ 0.186 log Fs	(2)
	(0.00)	(0.001)	(0.336)	(0.054)	(0.006)	
	R^2 =	0.31		F = 7.804		

The estimated model shows that the quantity of charcoal consumed by households in El-Salam Locality is a function of charcoal price (P_{Chr}), LPG price (P_{Lpg}), household income (Y), and household size (Fs). A change in charcoal price by one SDG changes charcoal consumption by 1.91 TOE, in the opposite direction. A change in LPG price by one SDG increases charcoal consumption by 0.065 TOE. A change in household income by one SDG changes charcoal consumption by 0.085 TOE in the opposite direction. Increase of family size by one more member increases charcoal consumption by 0.186l TOE.

All regressors are highly significant, except that of LPG price and income. R^2 is 31% indicating that the variations in the regressors explain 31% of the variation in charcoal consumption. Although the coefficient of the LPG price is not significant (significance level higher than 0.05), we kept the regressor in the model because the sign is correct and agrees with economic theory, more over its omission does not improves the model considerably (Wonnacott & Wonnacott, 1979). On the other hand the negative sign of the income coefficient indicates that charcoal is an inferior fuel that can be substituted by better fuels. Mekki (1984) found a similar result where the family income is negatively correlated with the quantities of the traditional fuel used and positively correlated to that of commercial fuel used.

iii. LPG consumption model

Equation 3 represents consumption function for LPG

Q_{Lpg} =	7.05 ED_{istw}	+ 2.966 Y	+11.04 RU	- 30.53 RO_{straw}	(3)
	(006)	(0.000)	(0.016)	(0.000)	
	R^2 = 0.38			F= 53	

The estimated model show that the quantity of LPG consumed by households in El-Salam Locality is a function of education level of first wife (ED_{istw}), household income (Y), and a dummy variable for room construction material (if all rooms are of straw, the variable = 1, else = 0). Improvement in the education level of first wife by one level increases LPG consumption by 7.05 TOE. Increasing income by one SDG increases LPG consumption by 2.966 TOE, other things being equal. Movement of one household from rural to urban areas, increases consumption of LPG by 11.04 TOE. Addition of one house made of straw decreases consumption of LPG by 30.53 TOE, other things being equal.

All regressors are highly significant. R^2 is 38% indicating that the variations in the regressors explain 38% of the variation in LPG consumption. All signs agree with economic theory.

DISCUSSION

Type of fuel:

Fuel consumption by households is affected by several socioeconomic factors. In this study, different issues were considered to reflect the general characteristics of households that may have relation to energy consumption. These characteristics include urbanization, family size, education level, income, type of house construction…etc. As El Salam locality is comprised of both urban and rural areas, it was expected that the pattern of energy consumption would vary accordingly. Urbanization was also related to the education level of household members which is, in turn related to household income. Although a sizable number of households in rural areas collect firewood free of charge

compared to urban areas (specially Babanosa), the percentage of those purchasing firewood is higher in all administrative units whether urban or rural. This supports what has been stated above about the difficulty of getting freely collected wood and also indicates that it is relatively cheaper to buy firewood than collect it or use alternative fuels. This is especially correct in the case of charcoal and LPG where LPG is the most expensive fuel per unit (because of the high transportation cost) followed by charcoal and firewood. This is contrary to other urban areas in the country where LPG is the cheapest fuel. Other factors may relate to the availability of the fuel itself. In the absence of infra structures (storage chambers) and reasonable level of demand for LPG, it becomes uneconomical to supply LPG to these areas. This has also been stressed by Hasab Elrasoul (1999) that petroleum fuel is not conveniently available in the rural areas. The type of fuel used is related to the education level of the head of household. In general terms, lower levels of education are associated to the more inferior types of fuel, and vise versa. This might also be related to the income level as education is closely related to income. As urban areas are relatively well-off and have better access to education services they are also associated to more modern types of fuel.

Levels of consumption:

The levels of consumption of fuels by households were studied using techniques of association, means separation and regression. On average, LPG represents the highest quantities of fuel (27.6 TOE) (see Table 4.6) used by households, followed by firewood while charcoal is of lowest quantity (0.33 TOE). However, the distribution of these quantities among administrative units reveals that the quantities are related to urbanization level. The more the area is urbanized the less fire wood or charcoal amount is consumed, and vice versa. The opposite is true for LPG, where the high amounts of consumption are related to urban (Babanosa mainly) and the low consumption amounts is related to the rural areas. Areas falling between the two categories (that is moderately rural or urban) are characterized by relatively moderate amounts of consumption. This distribution is probably related to the finding that in the average case fuels are used in combination and are replaced by modern fuels as the area becomes more urbanized. In the most urbanized areas only LPG is used, signifying high amounts of LPG, while in other less urbanized areas lower quantities of LPG are used due to the partial replacement by other fuels. This can also be said for the case of the other two fuels. Mekki (1984) stated that urbanization and geographical location were found to affect significantly the level and consumption of energy.

The education level of the head of household and first wife affects the level of fuel consumption variably. In general the more educated is the head of household the less firewood and more LPG is consumed, suggesting that either firewood is being used more efficiently or that firewood is being substituted for better fuels, namely LPG. In the case of the first wife, her education and income apparently lead to shifting from inferior fuels

to superior ones, other things being equal. This is especially true as, generally speaking, the first wife is the most powerful and controls the household decisions related to household management. Negligence of women roles in this regard has made many programs aiming to increase supply of fuel wood to fail (FAO, 1995).

iii. Factors affecting shift among fuels

The consumption function models revealed that consumption of firewood is mostly affected by the education level of the head of household and the availability of the alternative fuel within reasonable reach. The price of firewood and the family size have significant but less important effect. The education level is related to the income level of the household which means with higher income people will consume less of firewood and more of other superior fuels. Mekki (1984) finds that the source of income have significant effect on the composition and level of fuel consumption.

Although firewood is available free for part of the population in the locality, still its low price relative to other fuels encourages households to consume more of it. The availability of charcoal within reasonable reach would encourage households to consume less of firewood and more of charcoal. This is further supported by the effect of the charcoal price, as its relatively lower price would encourage households to shift to charcoal.

The consumption of charcoal is affected by income, the family size and LPG price. A shift from charcoal to LPG is discouraged by the relatively high cost of LPG. The high cost is mainly due to the transportation cost from production sites to consumption sites and the unavailability of storage chambers. Moreover, LPG is transported in bulky cylinders for long distances. The most important factor in LPG consumption is whether all rooms of the house are made of straw or not. When a house has all the rooms made of straw this decreases consumption by slightly less than one third. This is because the use of LPG in a kitchen built of straw imposes high level of risk of fire outbreak, and LPG devises are unsafe to be used in the yard outside the rooms.

Education of first wife is the second most important factor. Given the fact that the education of the first wife improves her income status and, therefore, encourages her to use better fuels, the first wife is expected to have more power in decisions related to household management than other members of the households. Education will even strengthen this power, other things being equal.

Whether the household is in the urban or rural areas is the third most important factor. This is associated with the availability of the fuel itself. It is expected that in big urban areas there are better storage and distribution facilities and more demand of LPG which encourages the transportation of the fuel through long distances. It is expected that the shift to modern fuels is faster in urban than in rural areas. FAO (1983), depending on the result of a similar study, projected that an overall decrease of 5% in the consumption

of biofuels would occur by the year 2000. Despite the improvement in LPG supply, the low figure is due to slow shift from biofuels in the rural area.

CONCLUSIONS

The study concluded that the type of fuel chosen by a household is affected by many factors. These factors relate to education, income, type of house construction material and relative cost of the fuel. It also revealed that changing in any of these factors will probably cause a shift to a different type of fuel or a new combination of fuels. Projection of changing factors may help in better planning.

Consumption of different fuels is affected by different factors to different extents. The shift from an inferior fuel to a superior one is affected by education level and the relative prices of fuels. The shift to LPG is hampered by the fact that most households use straw only as the main house construction material.

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